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[Scope of Claims]

[Claim 1] A two-dimensional free space bidirectional optical connection device, which adopts a bidirectional optical connection method for connecting arbitrarily selected integrated circuits on a one-to-one, one-to-multiple, or multiple-to-multiple basis, characterized in that the two-dimensional free space bidirectional optical connection device comprises: a light-emitting element for converting electronic signals into light signals; a wavelength-variable optical filter for transmitting a particular wavelength of light signals; an optical coupler for coupling optical signals into a waveguide; a slab-type waveguide for propagating light signals; an optical coupler for extracting the propagated light signals again out of the waveguide; a wavelength-variable optical filter for transmitting a particular wavelength of the extracted light signals; and a light-receiving element for converting light signals into electronic signals, and in that synchronizing signals and input/output signals are received/transmitted via these components.

[Claim 2] The two-dimensional free space bidirectional optical connection device according to Claim 1, wherein the light-emitting element for converting electronic signals into light signals comprises an organic semiconductor having a resonator structure.

[Claim 3] The two-dimensional free space bidirectional optical

connection device according to Claim 1, wherein the wavelength-variable optical filter for transmitting a particular wavelength of light signals sandwiches both sides of materials whose refractive index is variably controlled by heat, an electric field, and a magnetic field with a pair of reflectors and electrodes.

[Claim 4] The two-dimensional free space bidirectional optical connection device according to Claim 1, wherein the optical coupler for coupling optical signals into a waveguide and the optical coupler for extracting the propagated light signals again out of the waveguide are holograms or fine scatterers.

[Claim 5] The two-dimensional free space bidirectional optical connection device according to Claim 1, wherein the slab-type waveguide for propagating light signals is composed of a multilayer made of polymeric materials.

[Claim 6] The two-dimensional free space bidirectional optical connection device according to Claim 1, wherein the light-receiving element for converting light signals into electronic signals also uses the light-emitting element composed of the organic semiconductor described in Claim 2 to operate the light-emitting element by being subjected to reverse bias.

[Detailed Description of the Invention]

[0001]

[Field of the Industrial Application]

The present invention relates to a two-dimensional free space

bidirectional optical connection device for connecting between LSI chips, between modules mounted with a plurality of LSIs, or between boards.

[0002]

[Prior Art]

Computers which have supported advanced information societies include many highly-integrated LSI chips. Thus, there is a demand for a high-speed and high-density signal transmission between those chips, between boards, or between computers. Up to now, the packaging technology employing electric wirings has been leading the field. However, the packaging technology employing electric wirings is faced with problems such as transmission delay, an increase of mutual interference noises, or an increase in the calorific value of an apparatus, resulting from the increase in wiring capacity accompanied with the high speed and high density. Accordingly, such the packaging technology is reaching its limit. It has already been reported that there have been attempts to solve these problems through light transmission. In other words, some interconnections utilizing noninductiveness and redundancy of light and having a high degree of freedom are suggested.

[0003]

As the light-receiving element which plays a central role in this system, widely used is a light-receiving/emitting element of a flat type which is composed of a compound semiconductor mainly

constituted of an inorganic semiconductor, in particular, GaAs and the like. As a representative thereof, a document (SEED of IEEE Journal of Quantum Electronics, QE-24, p.1462 (1985)) or NECTechnical Papers, Vol. 46, No.8, p.63 (1993) discloses a light-transmitting/receiving element called VSTEP. These elements implement lower power consumption to some extent and the redundancy on a small scale. However, these elements are not essentially suitable for the integration with silicon materials which constitute an LSI chip, and has not exceeded the high-speed/high-density performance which has been achieved in the current packaging technology.

[0004]

On the other hand, also suggested is an idea of a so-called free space interconnection in which free propagation of light is utilized while a light source is remained to be a point. As a representative thereof, a document (Applied Physics Letters, 64, p.2931 (1994)) discloses a module substrate utilizing a glass waveguide and a holography. However, such the module substrate has not realized bidirectional transmission/reception on a large scale.

[0005]

[Problems to be solved by the Invention]

An object of the present invention is to provide a connection having a high degree of freedom which is suitable for the integration with a silicon element constituting an LSI and which utilizes frequency/temporal multiplexing to eliminate a so-called wiring

bottleneck.

[0006]

[Means for solving the Problem]

(1) As a transmission medium, a slab-type waveguide composed of an organic high polymer formed in a flat board shape is utilized.

[0007]

(2) An optical input/output coupler having a wavelength selection function is arranged on a guiding layer, and a control element for managing a wavelength to be selected is provided. With such the mechanism, control signals are distributed to each element, thereby arbitrarily controlling the connection state between the elements.

[0008]

(3) The LEDs composed of an organic semiconductor is arranged on the above-mentioned coupler. A part of the LEDs are used as light-emitting elements, and the reset of the LEDs are used as light-receiving elements by a forward/backward voltage application.

[0009]

(4) An LSI chip or module is arranged on the above-mentioned waveguide substrate, and a signal electrode of the light receiving/receiving element and a chip (or a module or a board) are connected with each other. It should be noted that necessary electric wirings are separately provided to drive the chip or module on the substrate.

[0010]

(5) A synchronous control element is arranged on the chip (or the module or the board) which is placed on the same waveguide. With such the mechanism, synchronizing signals are distributed to each element.

[0011]

(6) The periphery of the above-mentioned waveguide substrate is shielded by resin materials which absorb signal light from each light-emitting element or light noise signals from the outside. In this regard, a part for performing inputting/outputting with the outside is not limited thereto.

[0012]

[Operation]

(1) By using the slab-type optical waveguide substrate, the technology for plane packaging which is the same as in the prior art can be utilized.

[0013]

(2) Since occupied electric wirings for connecting between terminals such as LSIs are not provided, a packaging density can be enhanced without being constrained by the space for electric wirings. In addition, the function of arbitrarily changing the connection is applied to a method for temporal multiplexing and wavelength multiplexing, thereby making it possible to further improve the packaging density.

[0014]

(3) Light transmission is performed even when the high-density packaging is performed, thereby making it possible to prevent the problems of signal delay, induction noises, and heat generation of an element.

[0015]

(4) As described above, a bottleneck of a bus or transmission system is eliminated. Thus, a single element performance is improved by expanding the degree of freedom to select LSI design, and, in addition, the processing capacity of the whole system can be remarkably enhanced through parallel arithmetic processing utilizing a more advanced network.

[0016]

[Embodiment]

As a substrate, a silicon substrate with excellent flatness was used. A polyimide varnish is developed on a substrate by spin coating and is heated, thereby forming a polyimide thin film. As the polyimide varnish, OPI-2005 and OPI-1905 manufactured by Hitachi Chemical Co., Ltd. are used, respectively, to form a clad and a core, and a core film thickness is set to become a single-mode slab-type waveguide.

[0017]

On the uppermost layer (clad) of the slab-type waveguide manufactured as described above, a hologram is formed by anisotropic

dry etching (RIE) based on the photolithography and O_2 , thereby connecting the waveguide and the light-receiving/emitting element.

[0018]

Indium tin oxide (ITO) transparent electrodes are formed on the hologram by vacuum evaporation. Subsequently, a buffer layer is formed of a polyimide membrane, and then the ITO transparent electrodes are subjected to vacuum evaporation again, thereby forming an etalon (bandpass filter) element. The transmission center wavelength of the filter can be controlled at the value of a current caused to flow through the ITO electrodes in a lower layer by the thermo-optic effect of the polymer. It should be noted that response time of the variable-type filter is limited to about 10 msec by heat conduction or the like. However, liquid crystal materials or electro-optical materials are applied instead of polymer layers, thereby making it possible to improve the variable-type filter to obtain the response time of about 0.1 msec to 100 psec.

[0019]

On the element, an organic electroluminescence element composed of an organic semiconductor which is disclosed in a document (1994 International Workshop on Electroluminescence, Digest of Technical Papers, p.36) is manufactured by vacuum evaporation. In other words, as an organic semiconductor material, poly[2-methoxy-5-(2'-ethylhexyloxy-1, 4-phenylene) vinylene] (MEH-PPV) was used. On the element, an upper electrode constituted

of Ca is formed by vacuum evaporation, and the electrode and semiconductor layer are made into a pattern again with an appropriate size by the photolithography and RIE. The thus formed element is subjected to bias in a forward direction and is made into the light-emitting element, and the light-receiving element is subjected to reverse bias and is made into the light transmitting/receiving element. The characteristic of the light transmitting/receiving element is as follows. A drive voltage of light reception is about -10.0 V in light reception, and a quantum efficiency is about 20%. A drive voltage of light emission is +2.0 V, and a quantum efficiency of light emission is 1%.

[0020]

A plurality of LSI chips (a clock control element, a memory, an arithmetic processor, and the like) are arranged on the module substrate, and are wholly sealed with resin materials.

[0021]

[Effects of the Invention]

An optical interconnection according to the present invention is not provided with fixed electric wirings for connecting signal terminals included in the LSIs with each other. As a result, it is possible to prevent a lot of problems due to high-density wirings, that is, (1) induction noises, (2) transmission delay, (3) heat generation accompanied with the increase in power consumption, and the like. Further, these connections can be arbitrarily changed,

temporal multiplexing or frequency multiplexing is utilized, thereby making it possible to construct more advanced network. As a result, the improvement of the processing capacity to a large extent can be expected.

[Brief Description of the Drawings]

[Fig. 1] An explanatory diagram of a two-dimensional free space bidirectional optical connection method in which a plurality of LSI chips are arranged.

[Fig. 2] A sectional view of the two-dimensional free space bidirectional optical connection device along the line A-A' of Fig. 1.

[Fig. 3] A detailed sectional view of the device of Fig. 2.

[Description of Reference Numerals]

1. substrate 2. LSI board 3. signal light 4. input/output terminal
5. reception element 6. transmission element 7. hologram 8.
insulating layer 9. polymer sealer 10. n-type (p-type) organic
semiconductor layer 11. p-type (n-type) organic semiconductor layer
12, 14. electrode 13. refractive index varying layer.